(12) UK Patent Application (19) GB (11) 2 335 710 (13) A

(43) Date of A Publication 29.09.1999

(21) Application No 9806546.9

(22) Date of Filing 27.03.1998

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(51) INT CL[6]
F02C 6/12, F02B 37/10, F16C 17/02 17/24 17/26 32/06 33/00

(52) UK CL (Edition Q)
F1G GPB GPE
F2A AD36 A6E2
H2A AKH1 AKK3 AK117 AK120 AK121 AK214B AK215B AK217R AK220S AK303S AK601S AK602R AK607R AK611 AK613 AK614 AK616 AK800 AK803 AK807 AK817
U1S S1994

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GB 1428929 A GB 1149182 A GB 0891278 A
EP 0367406 A2 EP 0310426 A2 EP 0304259 A1
EP 0159146 A1

(58) Field of Search
UK CL (Edition P) F1G GPB GPC GPE, F2A, H2A
INT CL[6] F02B 37/00 37/04 37/10 37/11, F02C 6/00 6/04 6/10 6/12 7/00 7/06
ONLINE EPODOC WPI PAJ

(54) Abstract Title
Hybrid turbocharger with air bearings

(57) A hybrid turbocharger comprises a turbine 11,18, a compressor 14,53, and an electric motor/generator comprising rare earth permanent magnets 49, fixed to a shaft 19, and a stator 45 having a winding 46. The shaft 19 is supported by air bearings 20,21, each comprising a bush 28 surrounding a portion of the shaft provided with grooves, and supplied with air from the compressor via a passage 75. Alternative groove configurations are disclosed (figs. 3-7) and the grooves may be of different depths. In order to prevent the permanent magnets 49, from being overheated, the passage 75 supplies air to a gap portion 39 that communicates with a region 41 via slots (42 fig.9) in the adjacent bush 28. A thrust bearing 62, is also provided.

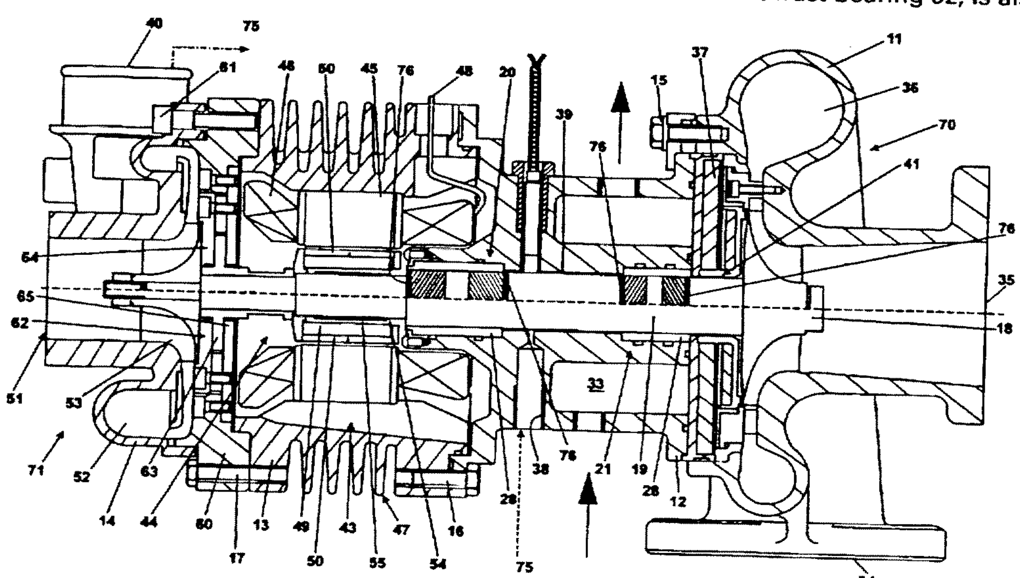

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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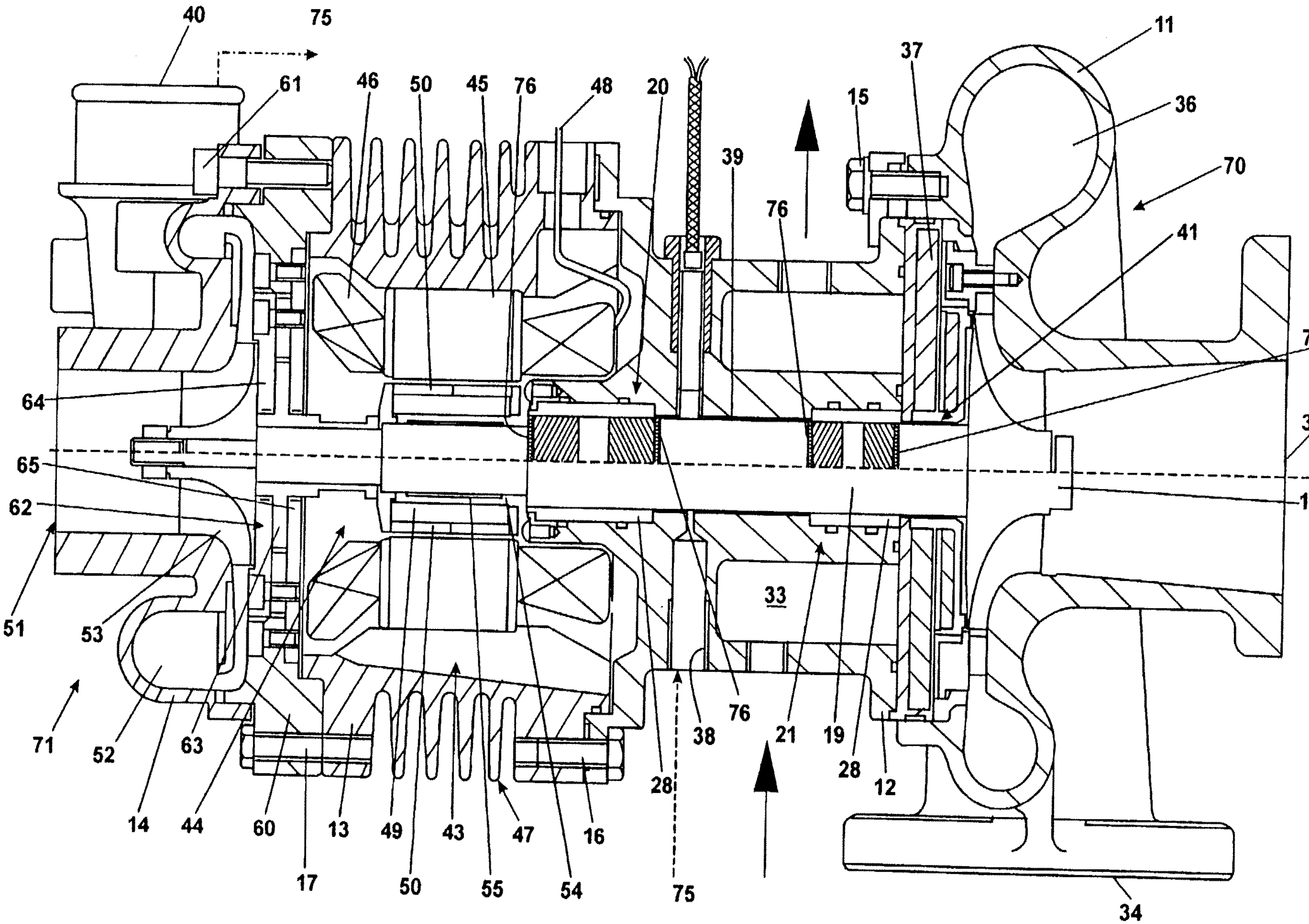

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FIG. 1

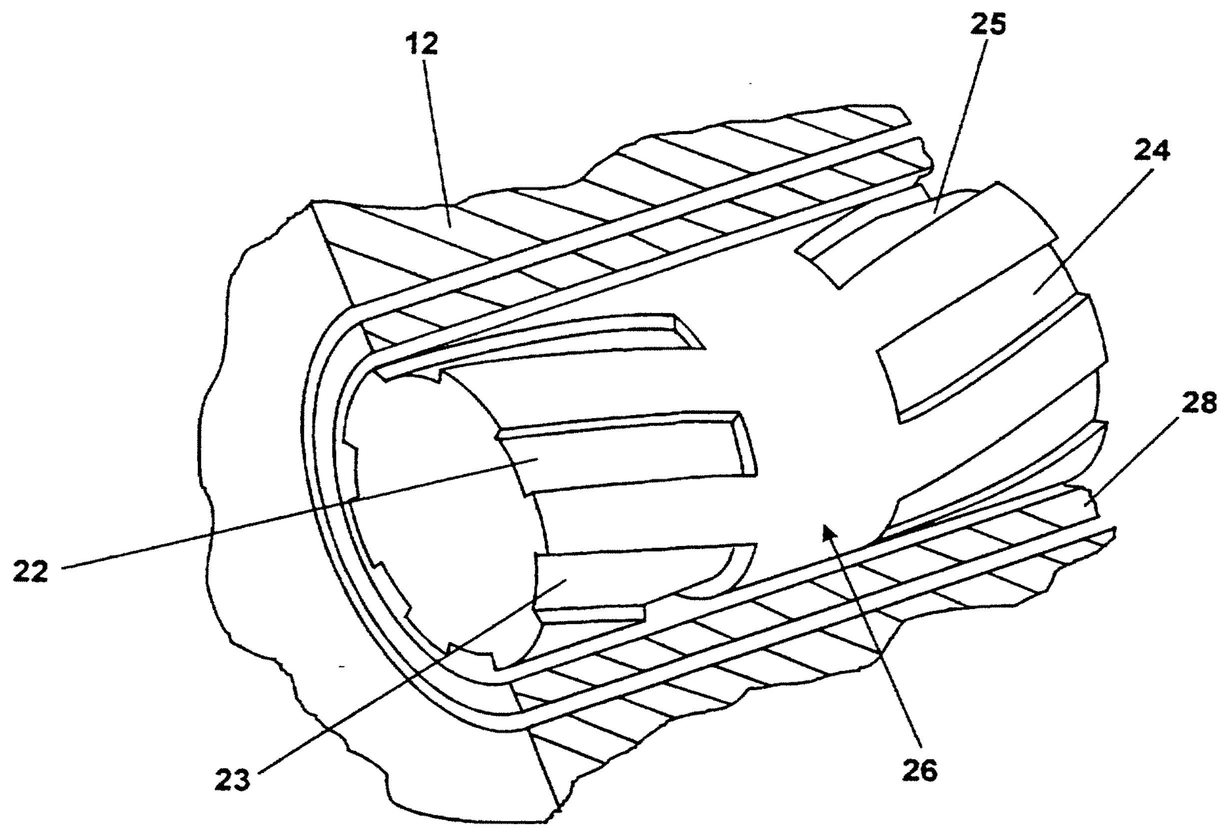


FIG.2

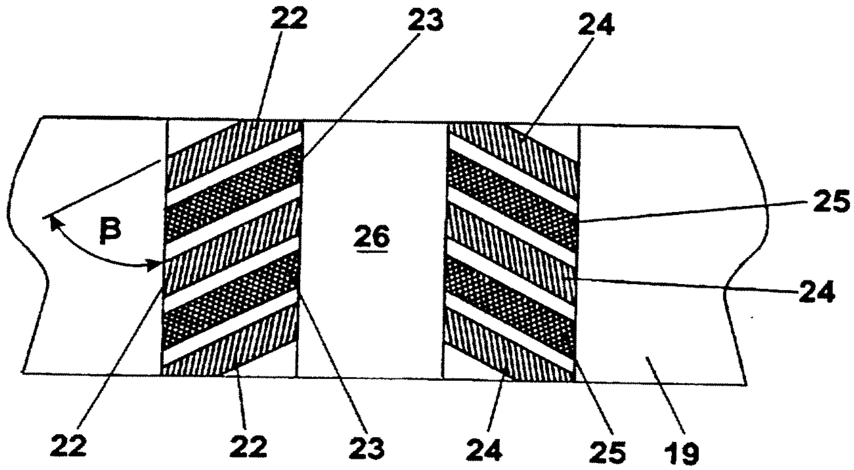


FIG.3

FIG.5

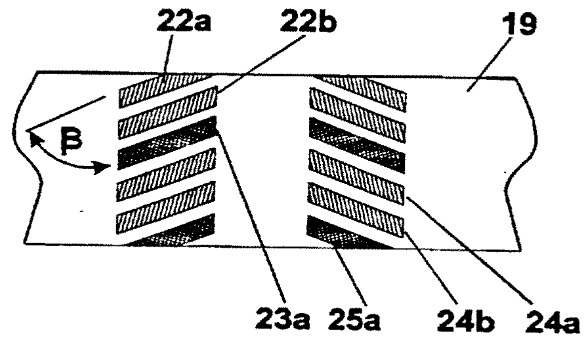
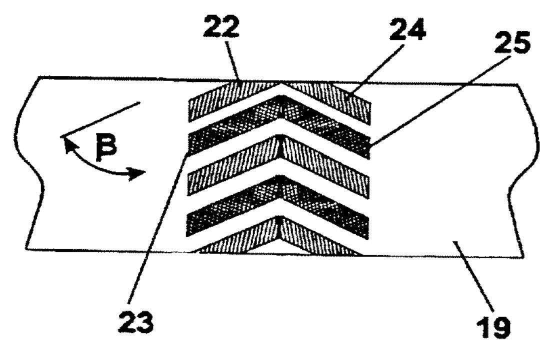


FIG.4



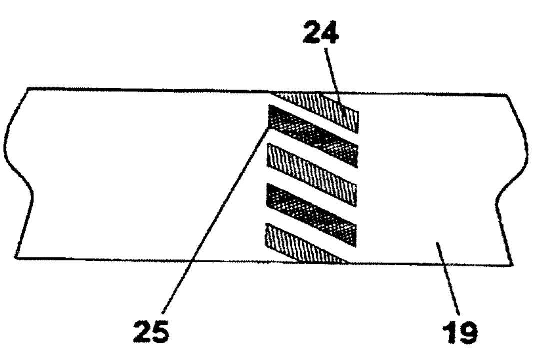


FIG.6

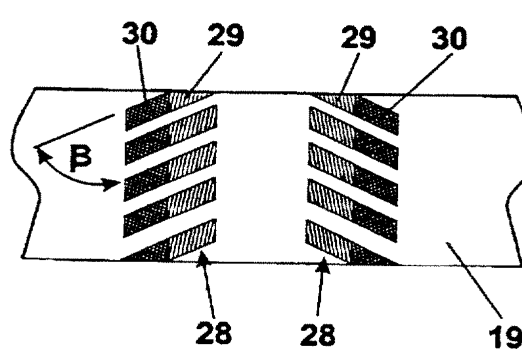


FIG.7

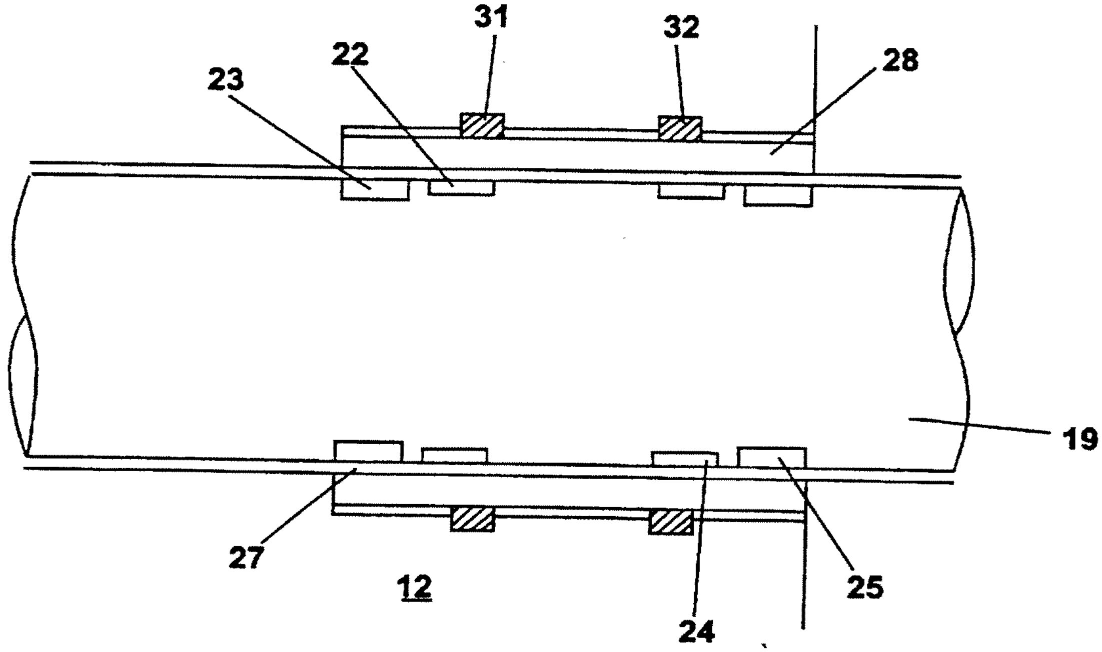


FIG.8

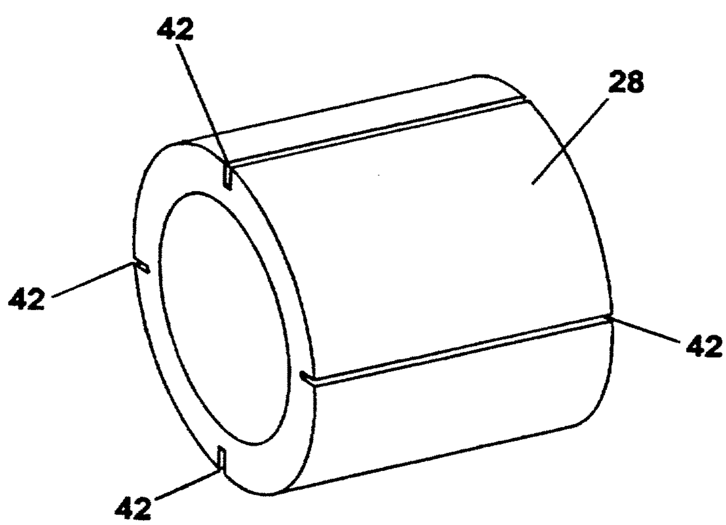


FIG.9

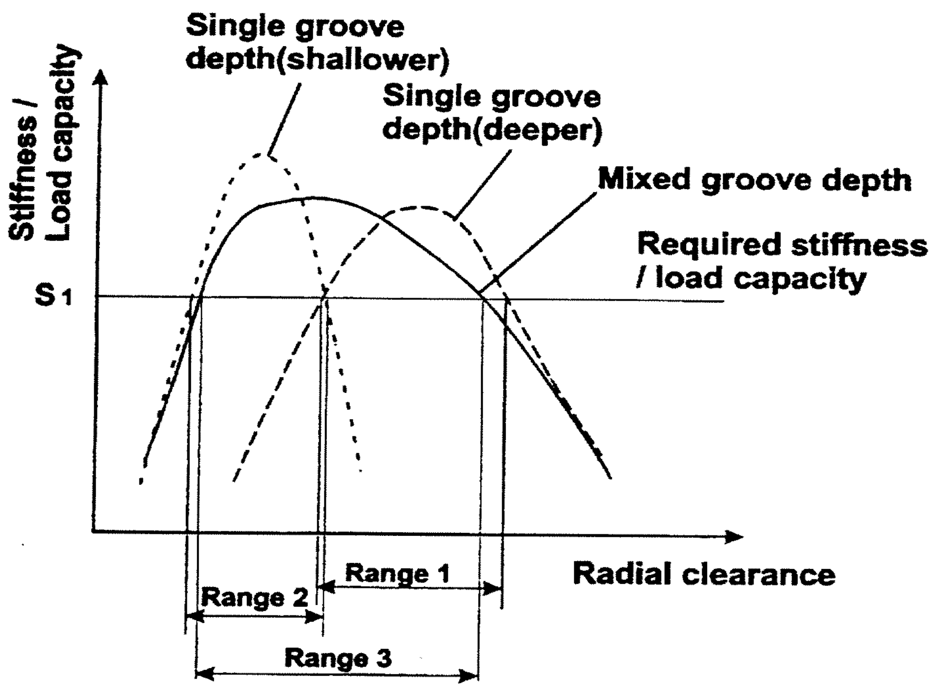

Single groove
depth(shallower)
Single groove
depth(deeper)
Mixed groove depth
Required stiffness
/ load capacity
Stiffness /
Load capacity
S1
Radial clearance
Range 1
Range 2
Range 3

FIG.10

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TITLE

Air Bearing Hybrid Charger

DESCRIPTION

Field of the Invention

The invention relates to an air bearing hybrid charger and in particular to an air bearing hybrid charger having a heat insulation mechanism.

Description of the prior art

Hybrid chargers are of interest in the automotive industry where they are being developed in connection with new technology vehicles. One example of such a new technology vehicle is the fuel cell powered electric car or hybrid car. An electric car is one powered by an electric motor or motors. A hybrid car is also provided with an internal combustion engine, and can take power from either or both of those two alternative power sources. Fuel cell technology involves the generation of electricity by the chemical reaction between hydrogen and oxygen, and in a fuel cell power source a hybrid charger is used to supply the oxygen to the fuel cell as compressed air. The hybrid charger amalgamates a turbocharger with an electric motor. The electric motor and the turbine impeller together or separately drive the compressor impeller of the turbocharger. The electric motor is powered by the electricity supply and the turbine impeller is driven by the exhaust gas of the fuel cell system.

Hybrid chargers may also be used to improve the power and efficiency of a conventional internal combustion engine. A hybrid charger can work an any of three ways depending on the working condition of the engine.

(1) It works as a turbocharger when the electric motor/generator is not working.

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(2) Both the electric motor and the turbine impeller can drive the compressor impeller to supply compressed air to the engine.

(3) When there is no need or little need for a turbocharger power boost, the turbine impeller drives the motor/generator as a generator to recharge the vehicle's battery, thus reclaiming a large proportion of the energy in the exhaust gas.

The catalogue of Allied-Signal Technologies discloses a conventional air bearing turbo-generator. The air bearing turbo-generator comprises a turbine rotor and a compressor rotor at two ends of a shaft and a generator rotor having a permanent magnet at the centre of the shaft. The shaft is rotatably supported on a housing through air bearings located inside of a bearing housing. Although the generator rotor is located near the high temperature turbine rotor, no heat insulation means is applied to the air bearing turbo-generator so as to prevent the generator rotor being overheated. The magnet of the generator rotor must therefore have a high thermal resistance. Otherwise the magnet will be in danger of being overheated and the performance of the turbo-generator will deteriorate. In order to improve the performance of the generator, rare earth permanent magnets, such as SmCo or NdFeb are commonly used. However, the thermal resistance is relatively low.

Summary of the Invention

It is an object of the invention to reduce heat transfer from a turbine side of a hybrid charger to a generator rotor having a permanent magnet.

In order to achieve the object, an air bearing hybrid charger comprises a housing rotatably supporting a shaft

via two air bearings, each air bearing comprising grooves formed on the shaft and a bush matching with the grooves; a motor/alternator comprising a first rotor having a permanent magnet, stator and a winding so as to be driven by an external electrical supply or to be driven by the shaft to generate electricity; a turbine rotor fixed to the shaft so as to be driven by gas flow and forming a turbine with a turbine inlet, a turbine outlet and a turbine scroll; a compressor rotor fixed to the shaft so as to form a compressor with a compressor inlet, a compressor outlet and a compressor scroll; and an air passage formed in the housing so as to supply compressed air from the compressor into a gap portion between the housing and the shaft, and between the two air bearings.

The air passage supplies compressed and preferably filtered air into the gap portion located between the housing and the shaft, and between the two air bearings. The increased air pressure in the gap prevents the exhaust gas from entering the gap from the back of the turbine therefore preventing not only the permanent magnets of the motor/alternator but also the shaft and the air bearings from becoming overheated.

Description of the Drawings

Fig. 1 is an axial section through an air bearing hybrid charger according to an embodiment of the invention;
Fig. 2 is an enlarged overview of the grooves, bush and housing of the air bearings of Fig. 1;
Fig. 3 is a front view of Fig. 2;
Fig. 4 to Fig. 7 are similar views to Fig. 3, but showing modifications of the grooves;
Fig. 8 is a cross-sectional view of the air bearing of Fig. 2;
Fig. 9 is an overview of a bush of Fig. 8; and
Fig. 10 is a graph showing the characteristics of the stiffness of the air bearing and the radial clearance

between the bush and the groove shaft forming the air bearing.

Detailed Description of the Invention

Fig. 1 shows an embodiment of an air bearing hybrid charger of the invention. A housing of the hybrid charger consists of five parts, a turbine housing 11, a radial bearing housing 12, a motor/alternator housing 13, a thrust bearing housing 60 and a compressor housing 14. The turbine housing 11 is fixed to the radial bearing housing 12 by a bolt 15 on one side thereof, the motor/alternator housing 13 is fixed to the radial bearing housing 12 by a bolt 16 on the other side thereof and an integration of the thrust bearing housing 60 and the compressor housing 14 is fixed to the motor/alternator housing 13 by a bolt 17. The compressor housing 14 is fixed to the thrust bearing housing 60 by a bolt 61 so as to complete the integrated housing. A turbine rotor 18 is fixed to one end of a shaft 19 and is located in the turbine housing 11. A compressor rotor 53 is fixed to the other end of the shaft 19 and is located in the compressor housing 14. The shaft 19 is rotatably supported in the radial bearing housing 12 via two air bearings 20,21.

Each air bearing 20,21 comprises a first set of inclined parallel shallow grooves 22,23 in the shaft 19 and a second set of inclined parallel shallow grooves 24,25 in the shaft 19 axially spaced from the first such set. The grooves 22,23 of the first set are inclined at an angle +ß with a plane normal to the axis of the shaft 19, and the grooves 24,25 of the second set are inclined at an angle -ß, so that the grooves form a herringbone pattern, as seen clearly in Figures 2 and 3. Spanning the two sets of grooves 22,23 and 24,25 is a bush 28, one for each air bearing. A surface 26 of the shaft 19 between the two sets of grooves 22,23 and 24,25 defines a so-called "pressure band" area to maintain the pressure that is

built up in use in the narrow annular space 27 (Figure 8) between the shaft 19 and the bush 28 and between the two sets of grooves 22,23 and 24,25. It is recommended that for each air bearing 20,21 the axial length of the pressure band is from 30% to 40% of the total bearing axial length.

Each bush 28 has an axial length no longer than, and preferably marginally axially shorter than, the axial length of the two sets of grooves 22,23; 24,25 with which it is associated. Each bush 28 has an internal diameter the same as or marginally less than that of the internal bore of the bearing housing 12 between the two air bearings 20,21. The grooves 22,23; 24,25 where they project beyond the axial ends of the associated bush 28 define a groove access zone 76 to permit access of the air into the grooves in use. If desired an annular groove may be formed in the internal bore of the bearing housing 12 or of the bush 28 around each air access zone 76 to enhance the air access.

In each set of grooves 22,23 and 24,25, the grooves 22,23 and 24,25 have alternatively two depths: one shallower groove 22,24 followed by a deeper groove 23,25, and then a shallower groove 22,24 again, so on.

Some modifications of the pattern of grooves are shown in Figs. 4, 5, 6 and 7. In Fig. 4, no pressure band is formed between the two sets of grooves 22,23 and 24,25. This modification is suitable for a hybrid charger where a short axial length is required. In Fig. 5, two shallower grooves, 22a,22b and 24a,24b are followed by one deeper groove 23a,25a, and then two shallower grooves 22a,22b, and 24a,24b again, and so on. Alternatively, two deeper grooves may be followed by one shallower groove, and then two deeper grooves again, and so on (not shown). In Fig. 6, only one set of grooves 24,25 is formed on the shaft 19

surface. This modification is suitable for a situation where the span of two air bearings is quite small and the grooves of two bearings form normally a symmetric pattern. The distance between the two bearings effectively acts as a large pressure band. In Fig. 7, the grooves 28 are all identical but the depth of each groove 28 is varied at an axial position along the groove 28. That is, each groove 28 comprises a shallower groove portion 29 and a deeper groove portion 30. The deeper groove portion 30 is located at the axially outer end of the groove 28 and the shallower groove portion 29 is located on the axially inner end of the groove 28.

Elastic O-rings 31,32 are located between the outer surface of the bush 28 of each air bearing 20,21 and the inner surface of the radial bearing housing 12 as shown in Fig. 8. The elastic O-rings 31,32 are made from Viton (Trade Mark) which has a low thermal conductivity and also acts as a so-called "flexible support" because of its elasticity. The elastic O-rings 31,32 allow the bush 28 to adjust its position, to extend, to accommodate its misalignment and to isolate itself from any distortion of the radial bearing housing 12.

Between the bearing 21 and the back of the rotor 18, a heat insulator 37 is located. A turbine inlet 34, a turbine outlet 35 and a turbine scroll 36 are integrally formed in the turbine housing 11 and form a turbine 70 with the turbine rotor 18. A water channel 33 is formed in the radial bearing housing 12 around the air bearing 21 near the turbine rotor 18 so as to cool the housings 11 and 12, so that the heat transfer from the turbine 70 to the air bearing 20,21 and to a motor/alternator 24 is reduced or greatly reduced. Air passage 38 is formed in the radial bearing housing 12 so as to be fluidically communicated with a gap portion 39 around the shaft 21 between the air bearings 20 and 21. Pressurized air is

supplied from a compressor outlet 40 through a passage 75 and a filter (not shown) to the air passage 38. The gap 39 is fluidically communicated with a region 41 between the air bearing 21 and the turbine rotor 18 through axial slots 42 of the bush 28, as shown in Fig. 9. The axial slots 42 are formed on the outer surface of the bush 28. The motor/alternator 43 located in the motor/alternator housing 13 comprises a rotor (first rotor 44) and a ring-shaped stator 45 having a winding 46. Radiator fins 47 are formed on the outer surface of the motor/alternator housing 13. One end of an electrical connection 48 is connected to the winding 46. The rotor 44 is fixed on the shaft 19 and comprises a yoke 54 and 4-pole rare earth permanent magnets 49, such as SmCo or NdFeB. On the inside cylindrical surface of the yoke 54, a recess 55 is formed so as to reduce the heat conducting from the shaft 19 through the yoke 54 to the permanent magnets 49. A cylindrical retainer 50 made from non-magnetic material holds the magnets 49 around the shaft 19. Since the present hybrid charger is driven at high speed, it is necessary to retain the magnets 49 around the shaft 19 via the retainer 50. Of course, other retaining means, such as bonding, are also available, if such retaining means can stand up to the high speed of rotation of the turbine rotor 18. The ring-shaped stator 45 is preferably made from magnetic material laminated in the axial direction so as to reduce eddy current losses.

The shaft 19 is also rotatably supported on the thrust bearing housing 60 via a thrust bearing 62. The thrust bearing 62 comprises a thrust bearing plate 63 fixed to the shaft 19 and two thrust bearing runners 64,65 fixed to the thrust bearing housing 60. The thrust bearing plate 63 is slidably held between the thrust bearing runners 64,65. A compressor inlet 51, the compressor outlet 40 and a compressor scroll 52 are integrally formed in the

compressor housing 14 and form a compressor 71 with the compressor rotor 53.

Specific operation of the embodiment is explained as follows. The turbine inlet 34 is connected to an engine (not shown) and the turbine outlet 35 is connected to a silencer or muffler (not shown). The compressor inlet 51 is connected to an air filter (not shown) and the compressor outlet 40 is connected to the engine. The exhaust gas of the engine drives the turbine rotor 18 and the rotor 44 of the motor/alternator 43 and the compressor rotor 53 via the shaft 19 at high speed. As a result, air is compressed in the compressor 71 and supplied to the engine. When the pressure of engine inlet is sufficient for engine requirements, the motor/alternator 43 may be functioned as an alternator to recover surplus energy of the exhaust gas. Due to the high-speed rotation of the rotor 44, a rapidly varying magnetic flux caused by the magnets 49 is produced in the winding 46 and electricity is generated at the motor/alternator 43 so as to charge a battery (not shown). On the other hand, when the pressure of the engine inlet is insufficient, the motor/alternator 50 may be functioned as a motor to improve the rotation speed of the shaft 19 (compressor rotor 53).

During the operation of the air bearing hybrid charger, the air passage 38 supplies pressurized air into the gap portion 39 around the shaft 21 between the air bearings 20 and 21. The pressurized air is furthermore guided to the region 41 between the air bearing 21 and the turbine rotor 18 through the axial slots 42 of the bush 28. The increased air pressure in the gap 39 and the region 41 prevents the exhaust gas from coming into the gap 39 and the region 41 from the back of the turbine rotor 18 therefore preventing the shaft 19, the air bearings 20,21 and the motor/alternator 43 from being heated by hot exhaust gas. Since pressurized air is delivered to the air

passage 38 through a filter, filtered air without undesired particles prevents the air bearings 20,21 from damage when filtered pressurized air is fed into the air bearings 20,21. The load capacity of the air bearings 20,21 increases with the increase of the pressure at the inlet of grooves 22,23,24 and 25. The introduction of pressurized air into the grooves 22,23,24 and 25 has a positive effect to increase the load capacity of the air bearings 20,21. Furthermore, some cooling effect by pressurized air is expected at the air bearings 20,21. The forced convection between the shaft 19 and the radial bearing housing 12 combining with the water channel 33 forms an effective heat transferring passage to bring significant amounts of heat away from the shaft 19. The low thermal conductivity of the O-rings 31,32 reduces heat transfer from the radial bearing housing 12 to the bush 28 and the shaft 19, so that very little change in radial clearance 27 between the shaft 19 surface and the bush 28 occurs due to temperature difference between the shaft 19 and the bush 28. The cooling of the water channel 33 protects the O-rings 31,32 from being overheated by the turbine 70.

The present air bearing hybrid charger has the above-mentioned good heat insulation at the air bearings 20,21. Some change of the radial clearance 27 between the shaft 19 and the bush at the air bearings 20,21 cannot however be completely avoided due to both centrifugal force and the thermal expansion of the shaft 19 caused by the temperature difference between the shaft 19 and the bush 28. Nevertheless, the air bearings 20,21 have good stiffness over a wide range of the radial clearance 27, as shown in Fig. 10, by using a combination of the shallower grooves and deeper grooves shown in Figs. 3 through 7. In Fig. 10, the shallower grooves 22 and 24 satisfy the required stiffness S1 in the range 1 of the radial clearance 27 and the deeper grooves 23 and 25 satisfy the

required stiffness S1 in the range 2 of the radial clearance 27. As a whole, the air bearings 20,21 satisfy the required stiffness S1 in the wide range 3 of the radial clearance 27 so as to correspond to the large change of the radial clearance 27.

CLAIMS

1. An air bearing hybrid charger comprising:

a housing rotatably supporting a shaft via two air bearings, of which each air bearing comprises grooves formed on the shaft and a bush matching with the grooves;

a motor/alternator comprising a first rotor having a permanent magnet, stator and a winding so as to be driven by an external electrical supply or to be driven by the shaft to generate electricity;

a turbine rotor fixed to the shaft so as to be driven by gas flow and forming a turbine with a turbine inlet, a turbine outlet and a turbine scroll;

a compressor rotor fixed to the shaft so as to form a compressor with a compressor inlet, a compressor outlet and a compressor scroll; and

an air passage formed in the housing so as to supply compressed air from the compressor into a gap portion around the shaft between the two air bearings.

2. An air bearing hybrid charger according to claim 1, wherein the air passage form in the housing is in communication with the compressor to supply a proportion of the compressed air delivered by the compressor in use into the gap portion around the shaft between the two air bearings.

3. An air bearing hybrid charger according to claim 1 or claim 2, further comprising at least one elastic O-ring located between the outer surface of the bush of the or each air bearing and the inner surface of the housing, wherein the O-ring has a low thermal conductivity.

4. An air bearing hybrid charger according to any preceding claim, further comprising at least one axial slot formed on the outer surface of the bush so as to form by-pass passage means for some of the pressurized air past

one of the air bearings and to that region between the air bearing and the turbine rotor.

5. An air bearing hybrid charger according to any preceding claim, further comprising a water channel formed in the housing around the one of the air bearings located nearer the turbine rotor.

The Patent Office

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Application No: GB 9806546.9
Claims searched: 1-5

Examiner: C B VOSPER
Date of search: 25 November 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1G(GPB,GPC,GPE); F2A; H2A

Int Cl (Ed.6): F02B 37/00,37/04,37/10,37/11; F02C 6/00,6/04,6/10,6/12,7/00,7/06

Other: ONLINE EPODOC, WPI, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 2298464 A	KOYO (fig. 1 - noting grooves 1d-2, and bush 4)	1
Y	GB 2108595 A	MOTOREN- (fig. 2, claim 13)	1
Y	GB 2064656 A	SKF (fig. 2 - noting grooves 36; page 2, lines 96-102)	1
Y	GB 1428929	ORMAT (whole document)	1
Y	GB 1149182	NETHERLANDS (whole document)	1
Y	GB 0891278	SAURER (page 1, lines 69-82)	1
Y	EP 0367406 A2	ISUZU (col.3, line 41-col.4, line 5)	1
Y	EP 0310426 A2	ISUZU (whole document)	1
Y	EP 0304259 A1	ISUZU (whole document)	1
Y	EP 0159146 A1	ISUZU (fig. 1; page 5, line 3 et seq.)(Equivalent = US4769993)	1

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